



Spacecraft Life Support Systems

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Temperature

Air

Radiation Protection

Food

Waste Removal

Water

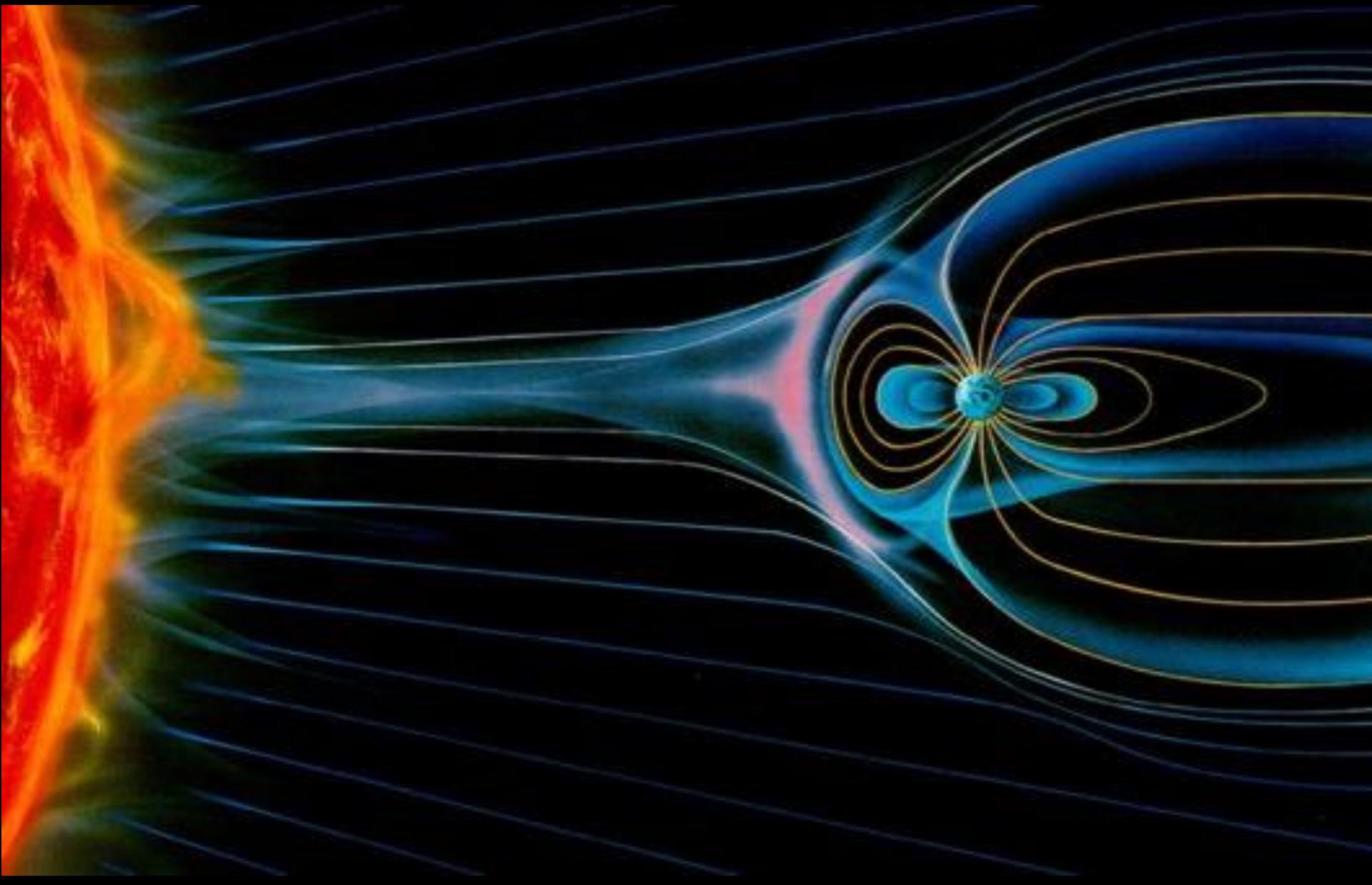
Gravity

Pressure





Earth's Life Support Systems (ELSS)



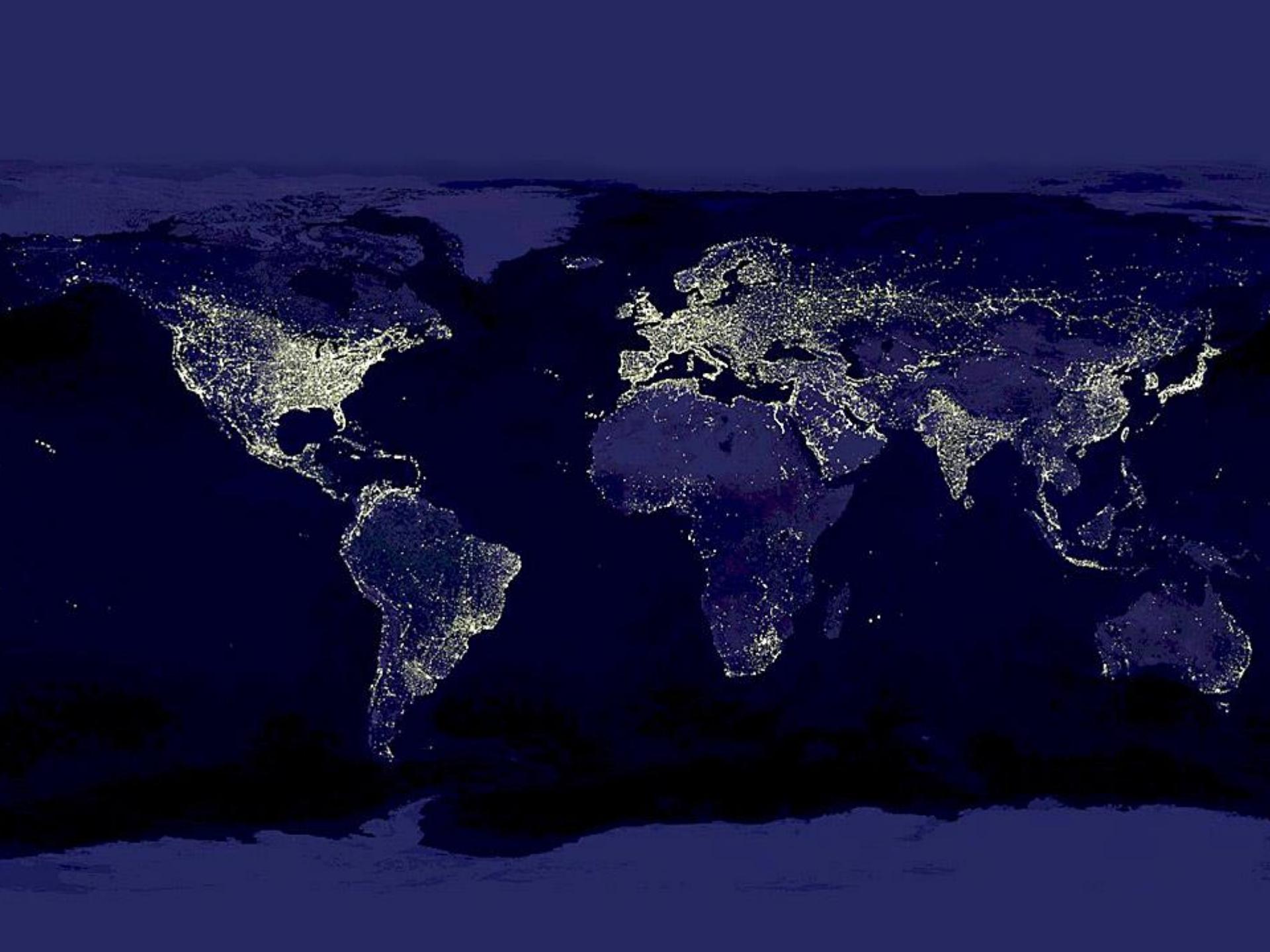
Human's Life System/Systems

Water/waste
purification

Air quality
regulation

Aesthetic/Spiritual values
Recreation/Ecotourism







Human Space Exploration

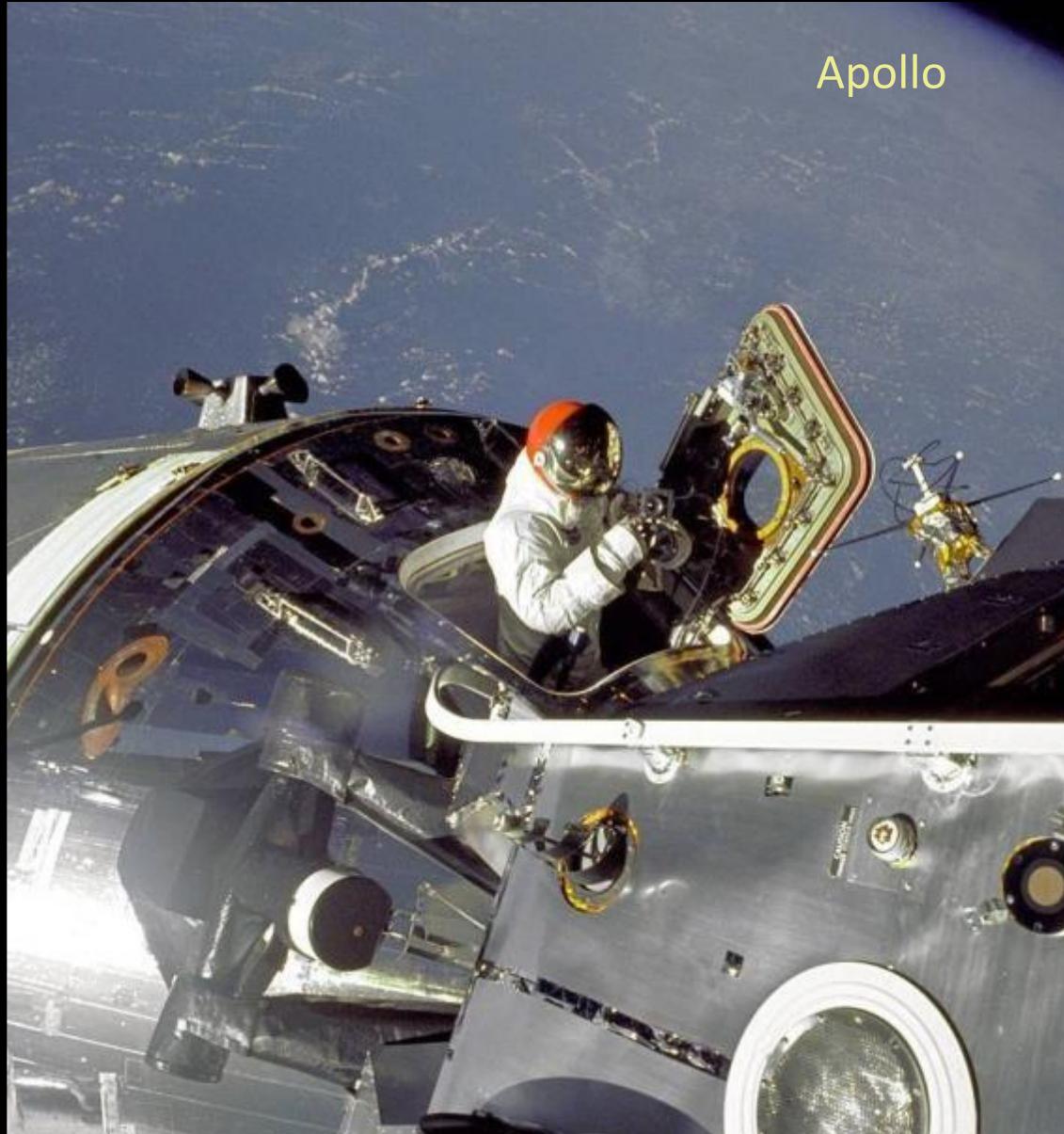




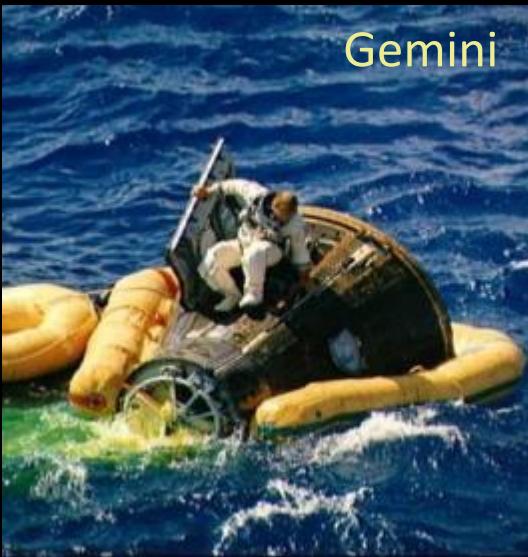
Early Missions



Mercury



Apollo

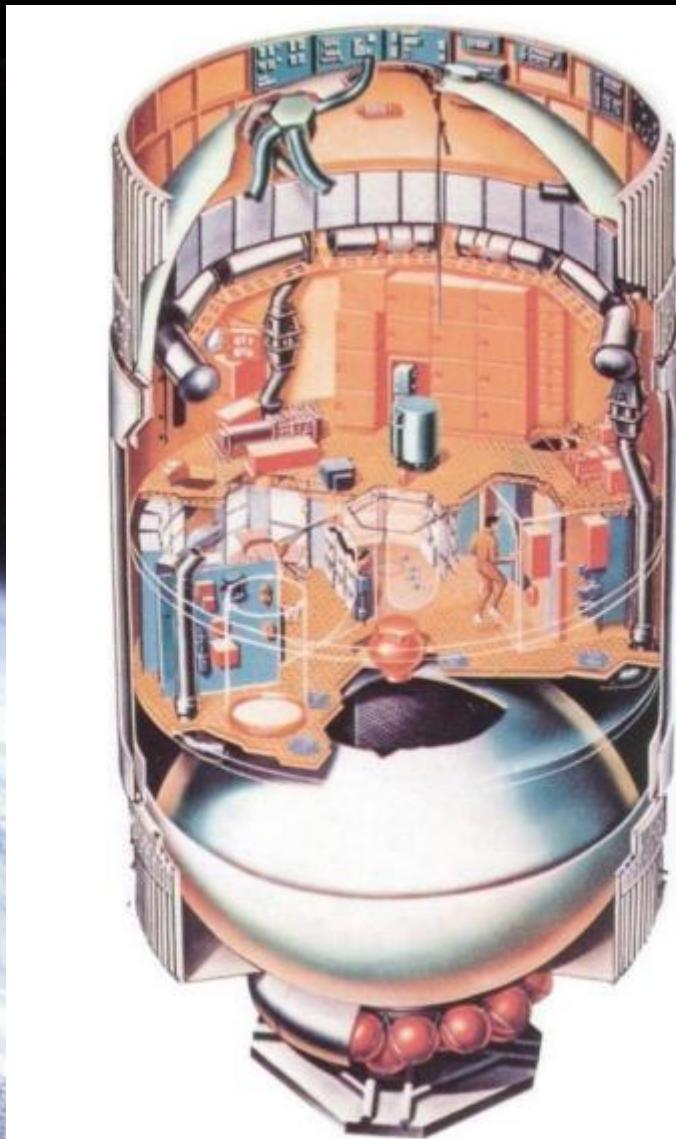


Gemini



SKYLAB

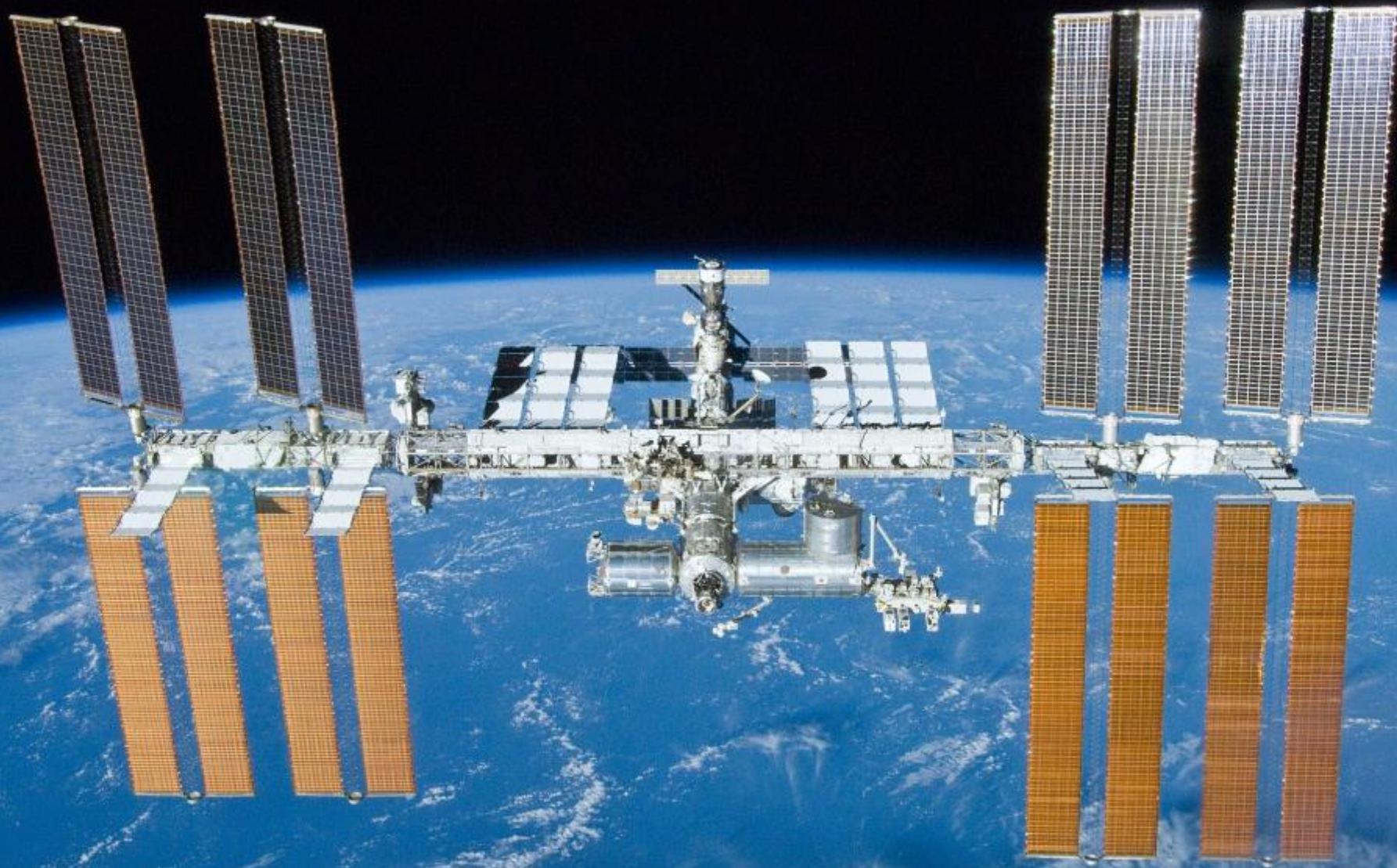
3 Missions - 28, 59, 84 days





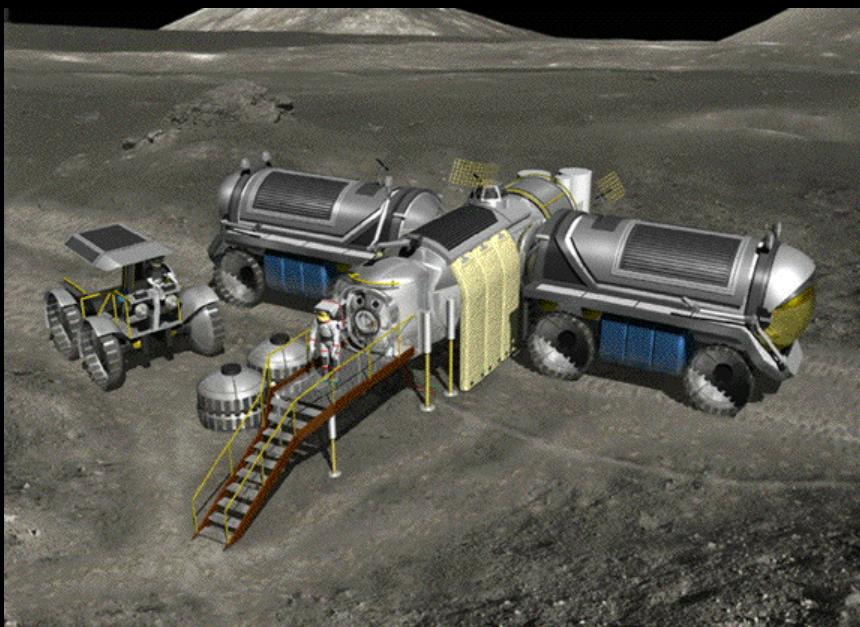


International Space Station



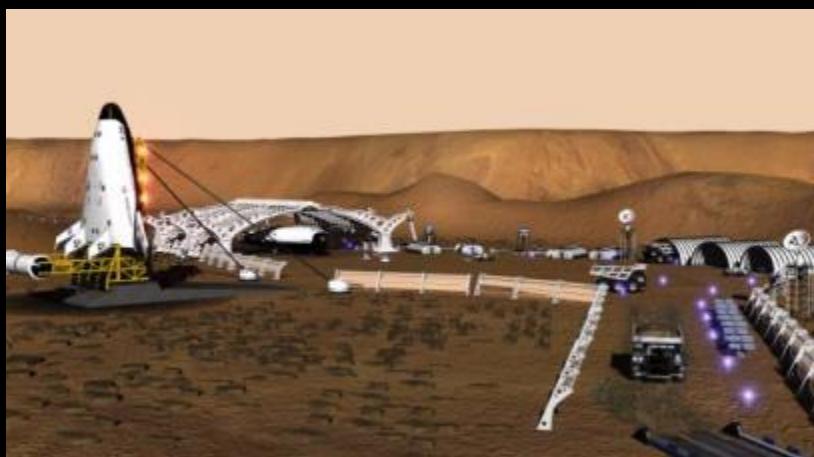
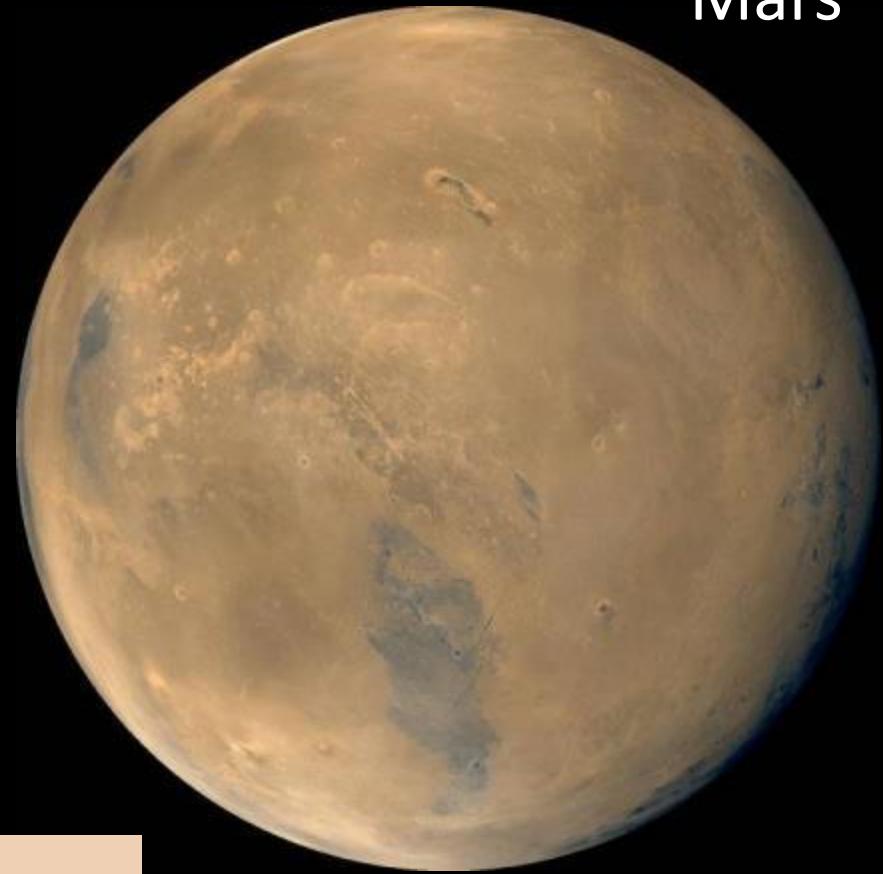


Luna





Mars





Atmosphere Management



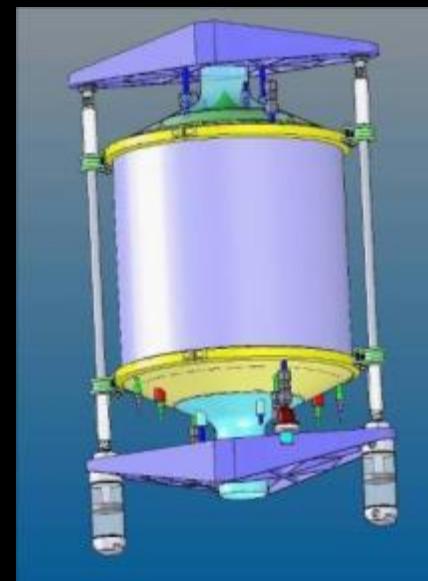
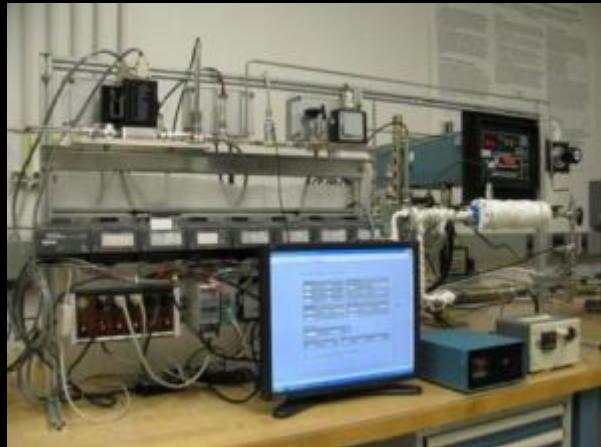
Air Revitalization



- O_2 Generation
- CO_2 Removal
- Contaminant Control
- Particulate Control



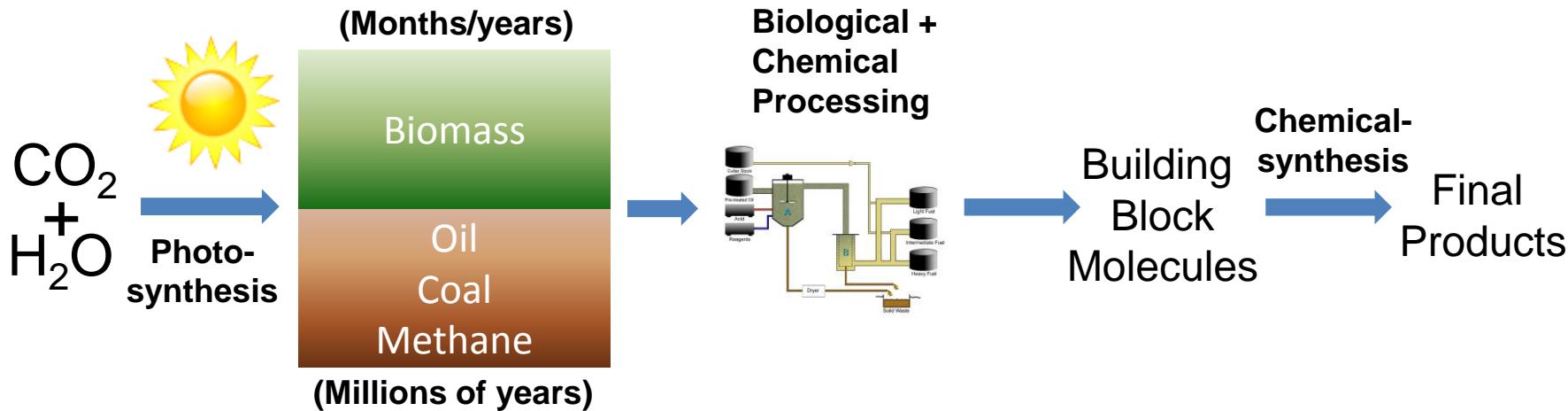
CO₂ Capture and Sequestration



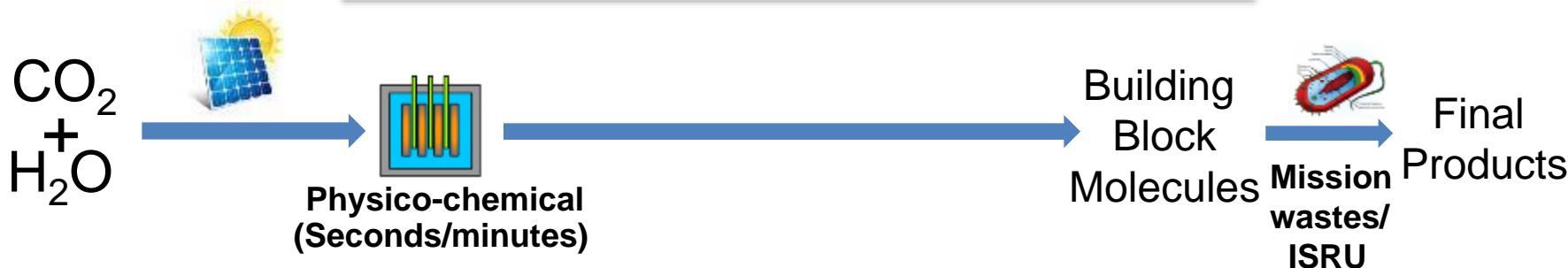


CO₂-Based Manufacturing Approaches

Current Terrestrial Biorefinery Model

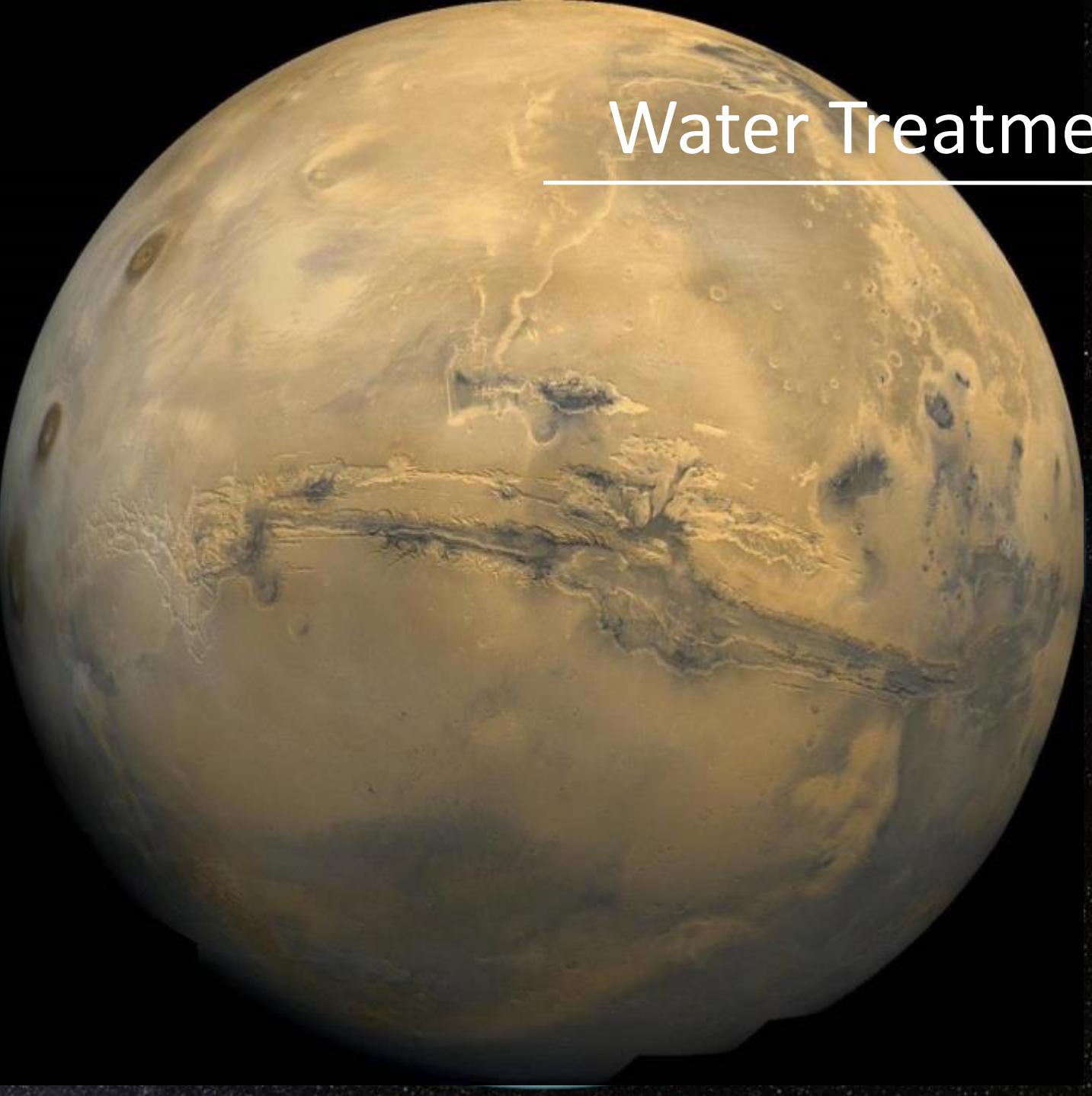


Space Bio-Manufacturing Model



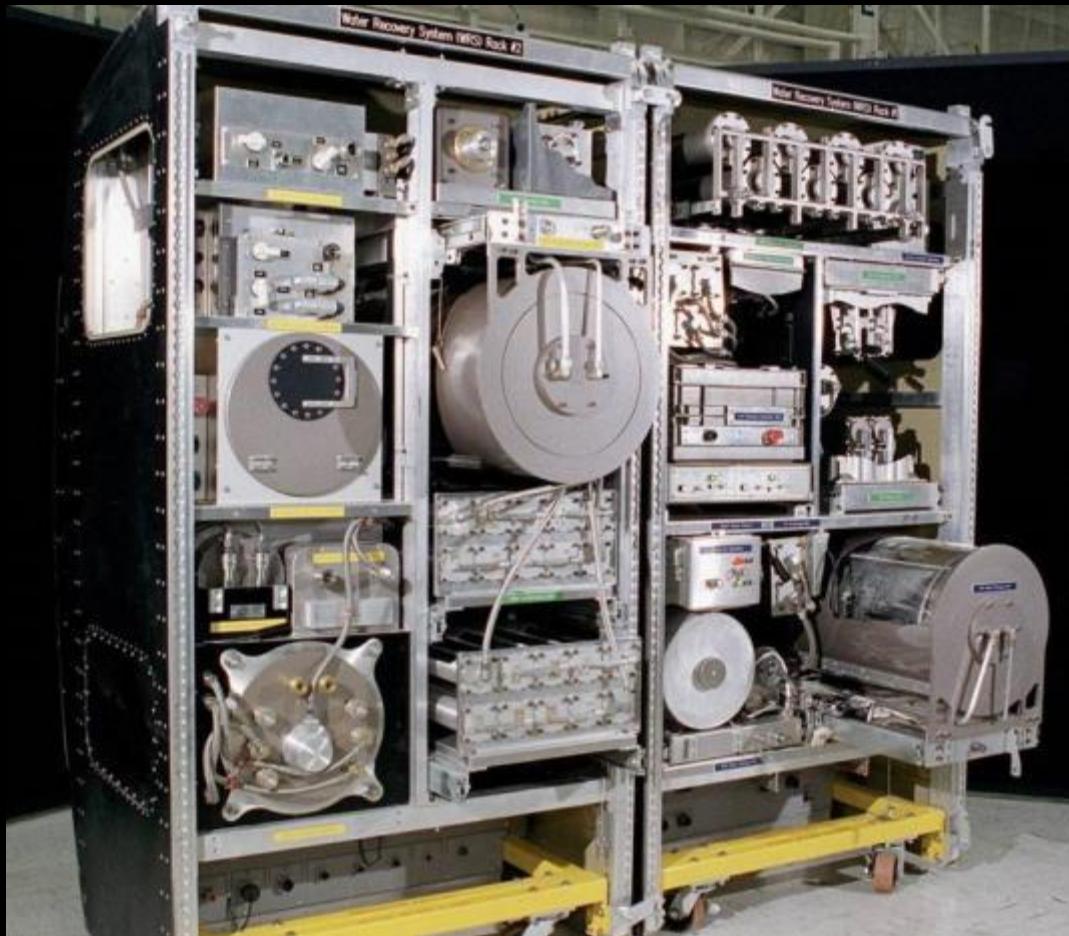


Water Treatment





Wastewater to Drinking Water

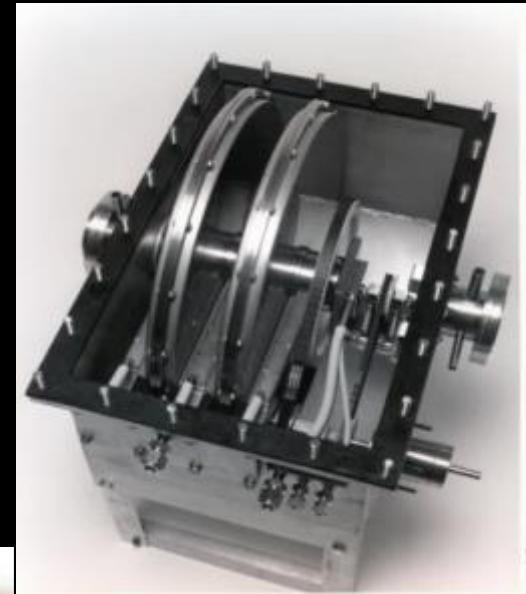
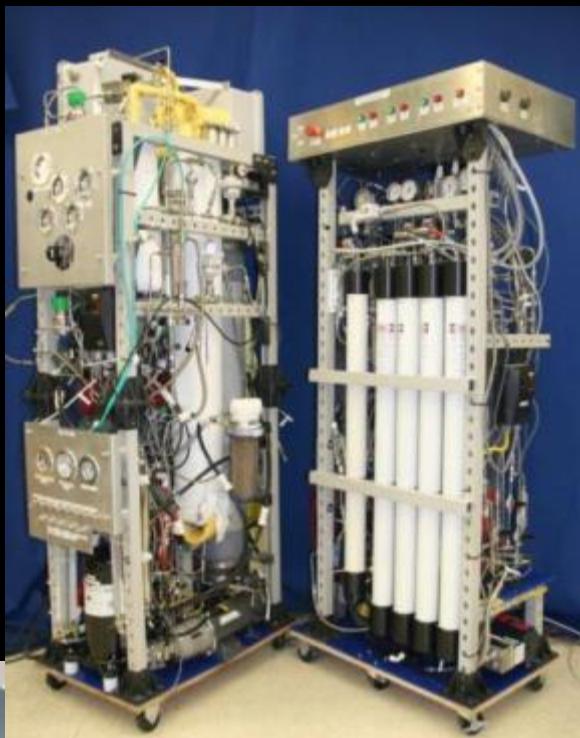


- Disinfection
- Organic Removal
- Inorganic Removal
- Maximize Recovery

ISS Water Recovery Subsystem

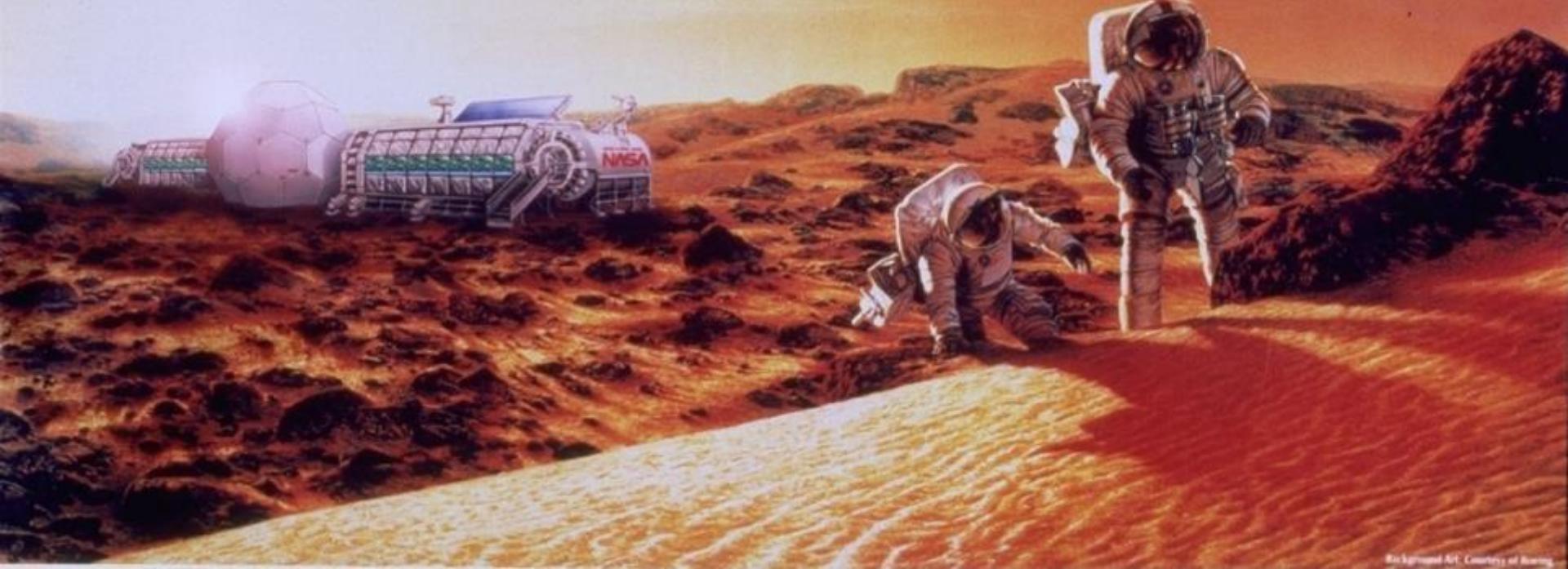


Closed-Loop Water Treatment



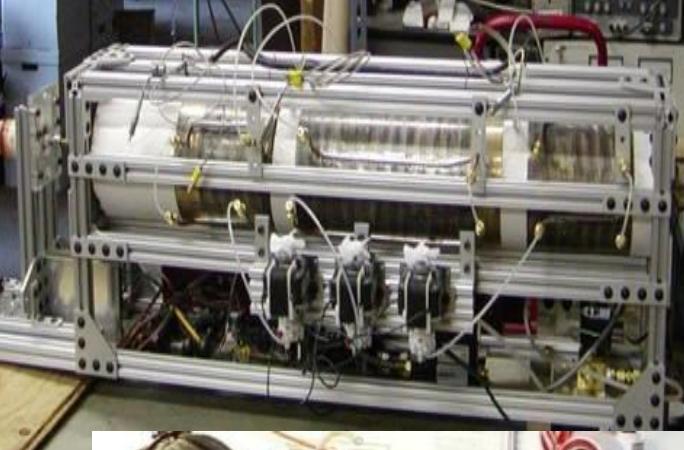
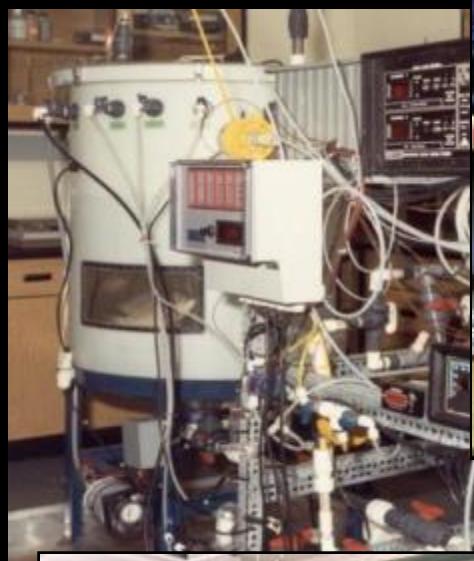


Waste Management





“Waste” Conversion and Reuse (“Cradle to Cradle” Approaches)



- Volume Reduction
- Odor Control
- Sanitize
- Generate H_2O , O_2 , CO_2 , Fuel, Nutrients, Building Materials



In Situ Manufacturing

Utilize unusable mission materials and *In situ* resources to generate products needed for sustainable systems.



Concept Example:

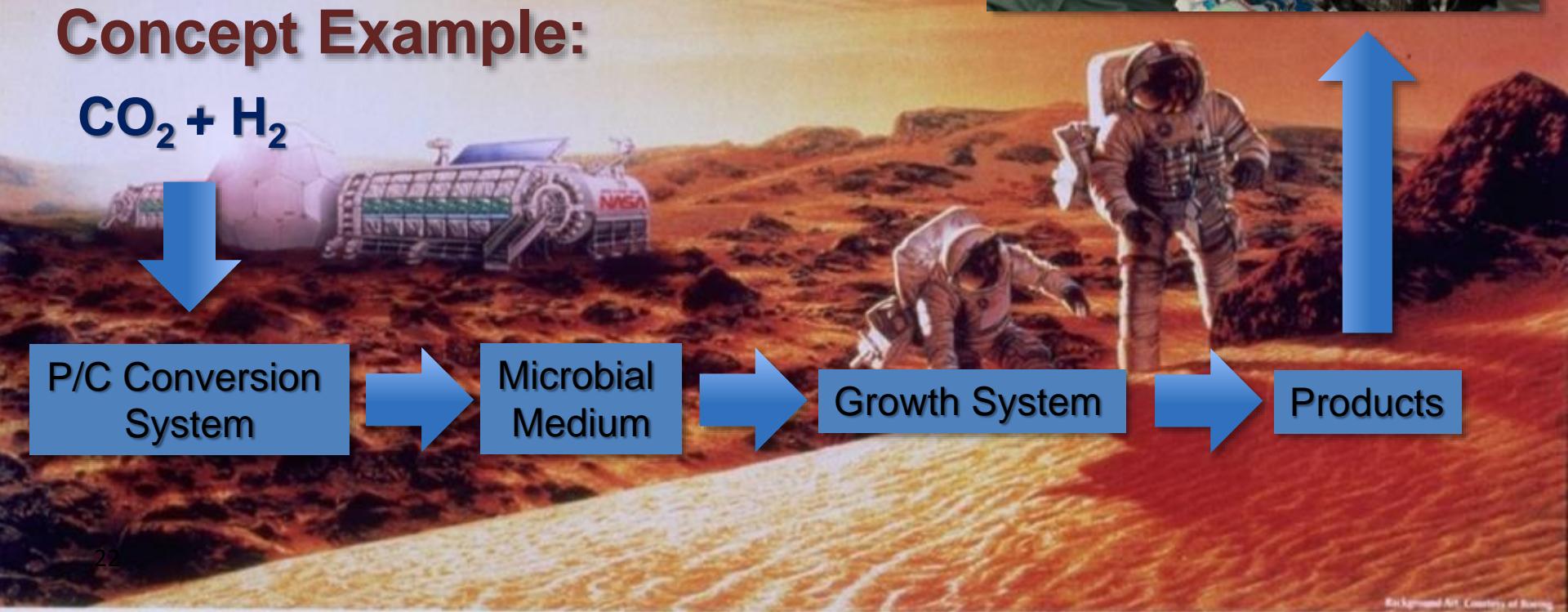


P/C Conversion System

Microbial Medium

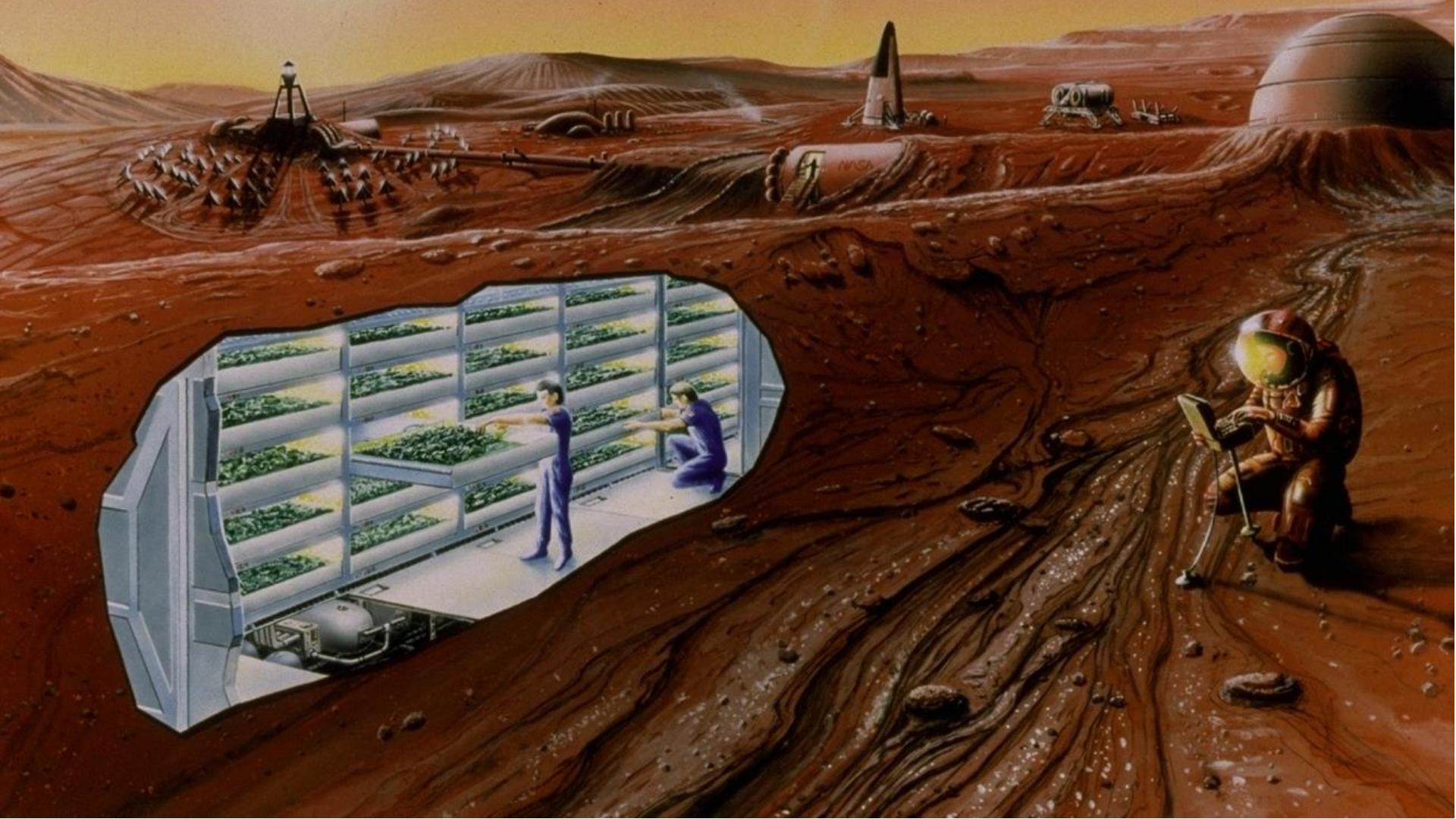
Growth System

Products



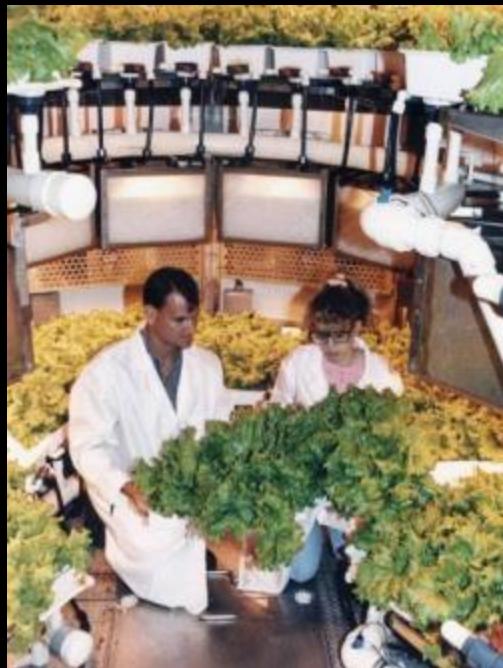


Food Production





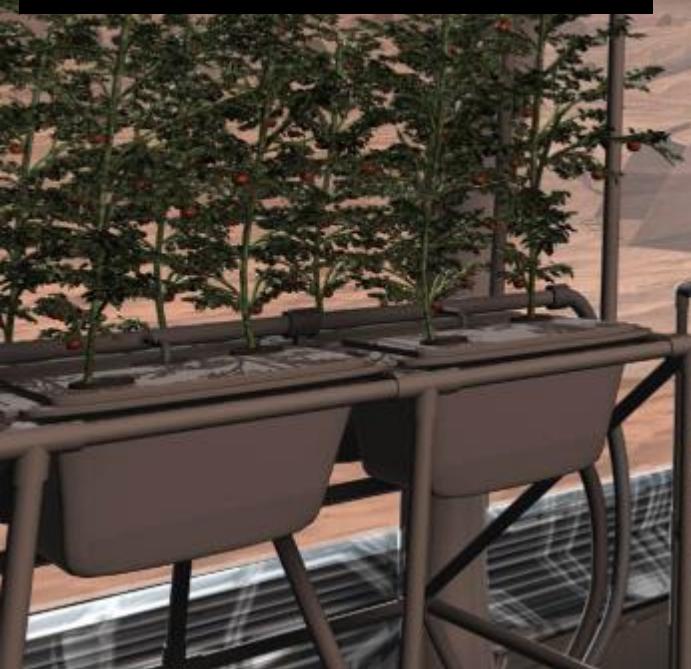
Closed System Agriculture



- Maximize Yield
- Low Water
- Efficient Lighting
- Use recovered nutrients



*Wheat - 3-4 x World Record
Potato - 2 x World Record
Lettuce-Exceeded Commercial
Yield Models*





Systems Engineering





Systems Engineering

Earth Systems Program

ELSS-RQ35484-C

Earth Life Support Systems Requirements Document

ESD – 34794

Earth Systems Directorate
Requirements Division

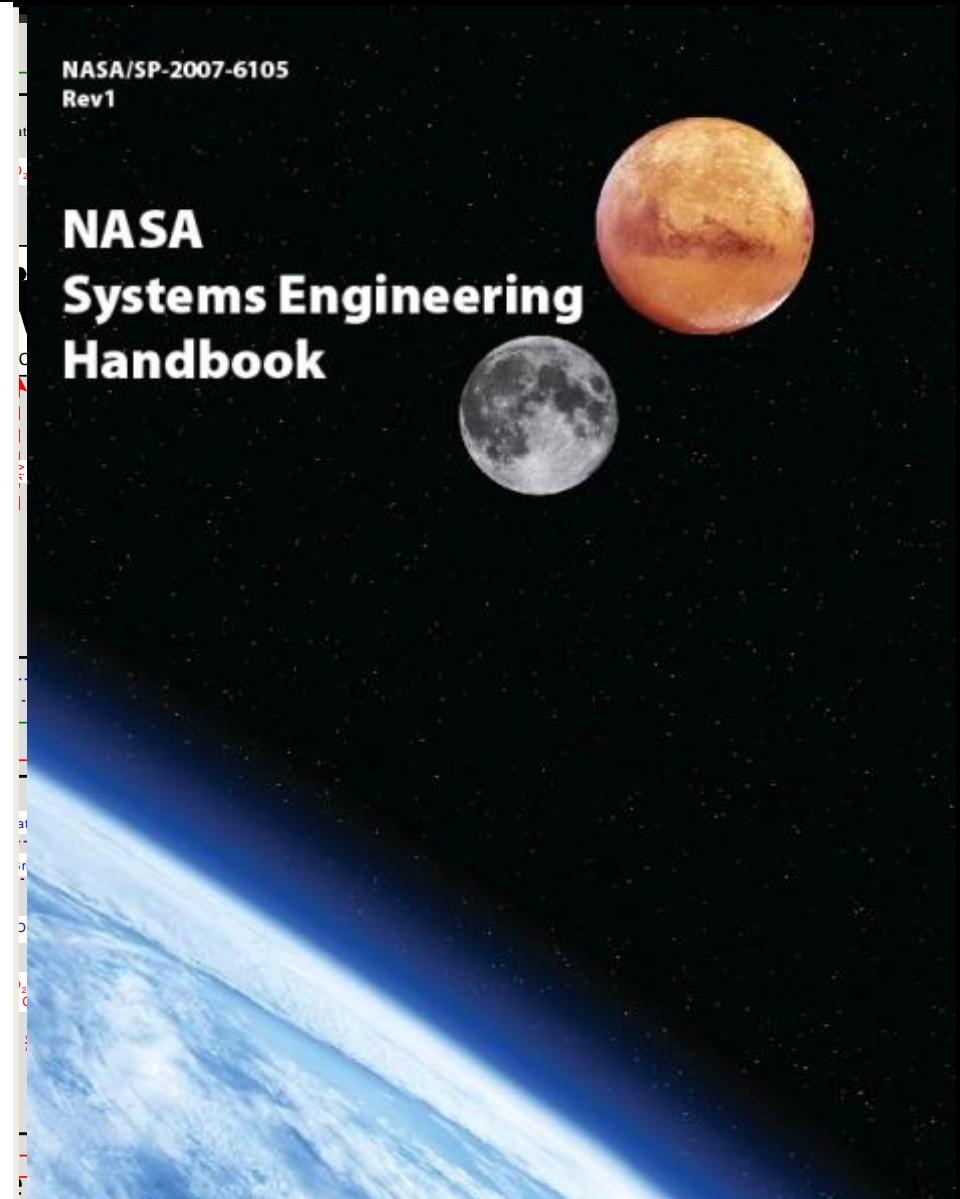
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Mountain View, CA 94035

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NASA Systems Engineering Handbook





Thank You